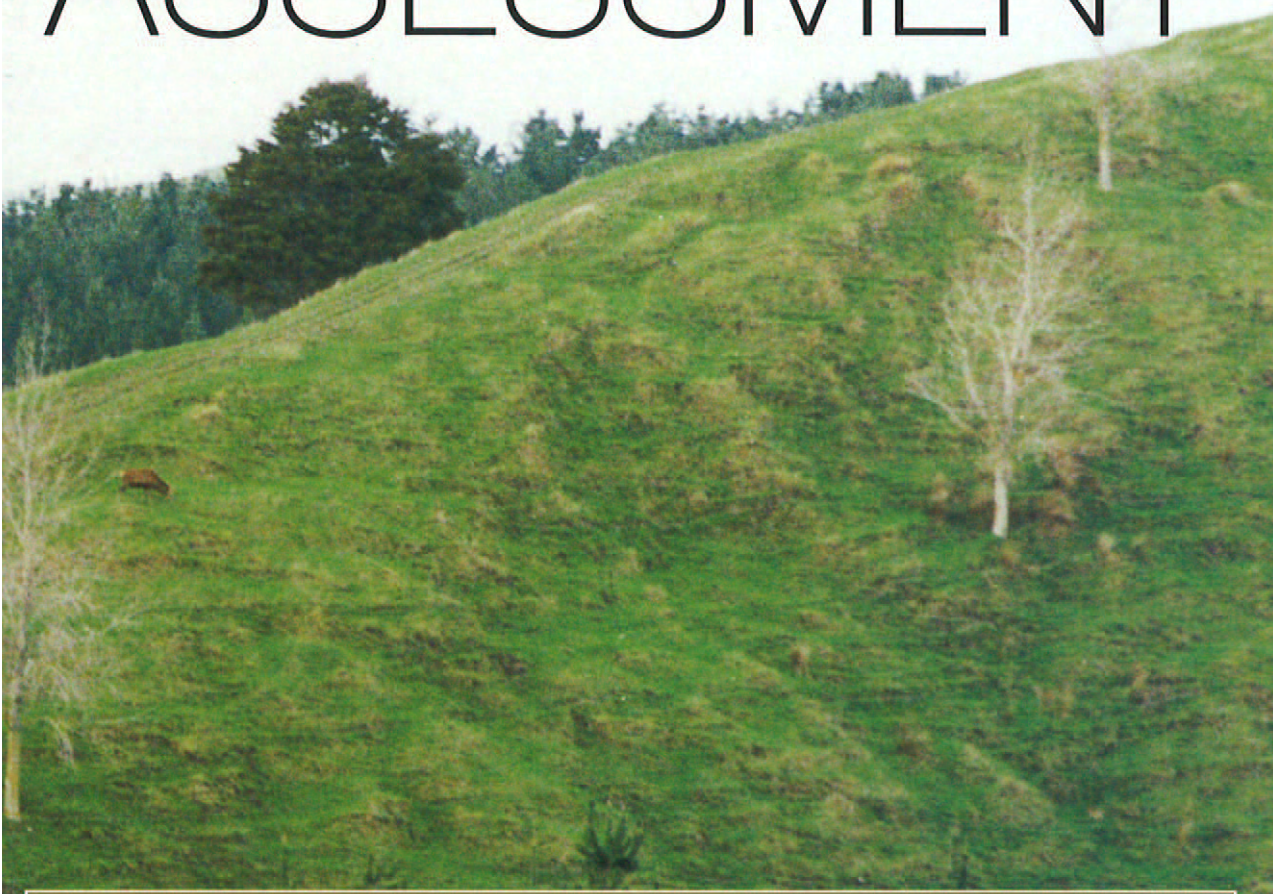
Volume 3

VISUAL SOIL ASSESSMENT

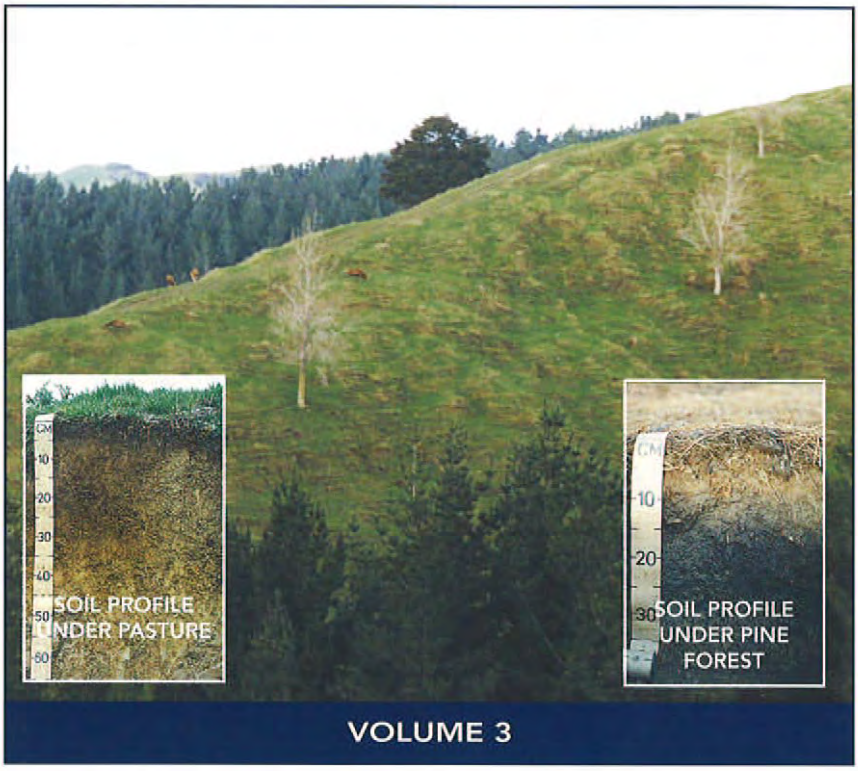


FIELD GUIDE

hill country land uses

Graham Shepherd & Helmut Janssen

VISUAL SOIL ASSESSMENT



Field guide for hill country land uses

Graham Shepherd and Helmut Janssen

VISUAL SOIL ASSESSMENT

Volume 3: Field guide for hill country land uses

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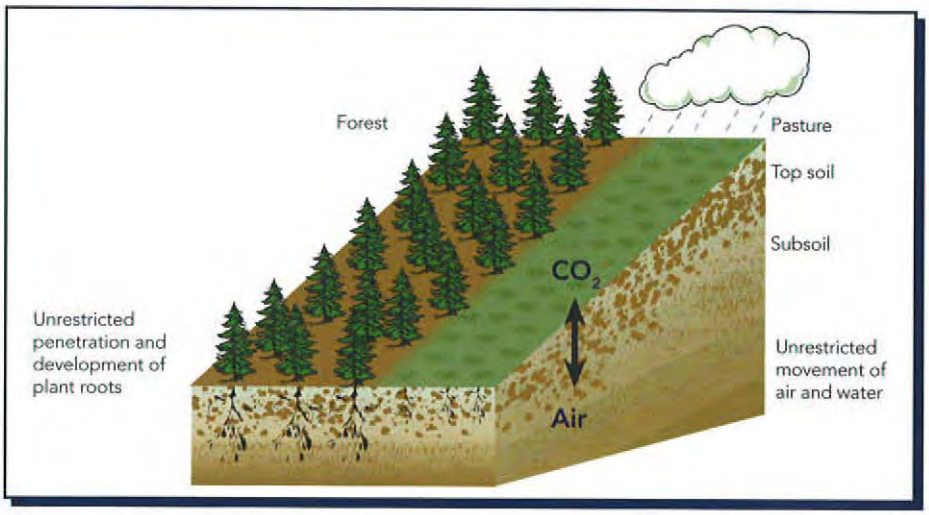
INTRODUCTION

THE QUESTION – To profit or to pug?

The soil's physical properties are vital to the ecological and economic sustainability of land. They control the movement of water and air through the soil, and the ease with which roots penetrate the soil. Damage to the soil can change these properties and reduce plant growth, regardless of nutrient status. Decline in soil physical properties takes considerable expense and many years to correct, and can increase the risk of soil erosion by water or wind. This is particularly so for hill country soils that are more susceptible to physical degradation than lowland soils, and do not have the management options for improvement available on flat to rolling country.



The primary functions of the soil are to provide plants with air, water, nutrients and a rooting medium for growth and physical support.

Safeguarding the soil resource for present and future generations is a key task of land managers. Loss of soil quality (soil degradation) can significantly affect the environmental sustainability of the soil, and the economic sustainability of farming businesses.

There is more to measuring soil quality than just assessing carrying capacity, growth rate of forest stands, or soil fertility. Often, not enough attention is given to:

- the basic role of soil quality in efficient and sustained production
- the effect of soil quality on the farm's or forest's gross profit margin
- the long-term planning needed to sustain good soil quality
- the need for land managers to be able to identify and predict the effects of their short- and medium-term land management decisions on soil quality.

As a land manager, you need reliable tools to help you make decisions that will lead to sustainable land management. The way you manage your farm has profound effects on your soil, and your soil has profound effects on your long-term profit.

THE ANSWER – Visual soil assessment (VSA)

Many physical, biological and, to a lesser degree, chemical soil properties show up as visual characteristics. Changes in land use or land management can markedly alter these. Research in New Zealand and overseas shows that many visual indicators are closely related to key quantitative (measurement-based) indicators of soil quality.

Visual assessment provides an immediate, inexpensive and effective diagnostic tool to assess soil quality, and the results are easy to interpret and understand. An example of this is illustrated in the photograph opposite, where a well-managed unpugged soil on the left of the palm, is compared with a pugged soil on the right.

These relationships have been used to develop VSA. The VSA Field Guide has been developed to help land managers assess soil quality easily, quickly, reliably and cheaply on a paddock scale. It requires little equipment, training or technical skills. Assessing and monitoring soil quality on your farm with VSA, and following guidelines for prevention or recovery of soil degradation, can help you develop and implement sustainable land management practices.

The VSA method

VSA is based on the visual assessment of key soil 'state' and plant 'performance' indicators of soil quality, presented on a score card. Soil quality is ranked by assessment of the soil indicators alone. It does not require knowledge of paddock history. Plant indicators, however, require knowledge of immediate pasture, tree crop and paddock history. Because of this, only those who have this information will be able to complete the plant indicator score card satisfactorily.

Plant indicators extend or qualify the soil quality assessment to allow you to make cause and effect links between management practices and soil characteristics. By looking at both soil indicators and plant indicators, VSA links the natural resource (soil) with plant performance and farm enterprise profitability. Because of this, the soil quality assessment is not a combination of the 'soil' and 'plant' scores. Rather, the scores should be looked at separately, and compared.

The following examples illustrate the practical application of VSA:

- A farmer records good pasture growth and, as a result, thinks 'things are fine'. But on applying VSA, the farmer discovers that the soil quality score is moderate, and realises that fertiliser requirements, have been increasing over time, along with the cost. With this knowledge, the farmer can make choices so that appropriate future management can lead to reduced input costs, increase profitability and improve soil quality.
- A farmer wants to expand grazing capability by leasing or buying additional land. VSA can provide important information about the soil quality of the land under consideration, which can help the farmer decide whether to lease/buy, or look for an alternative block of land.

VSA provides a useful educational and vocational training tool for those unfamiliar with soil science. It can bring a better understanding of soil quality and its fundamental importance to sustainable resource and environmental management. In particular, VSA can develop a greater awareness of the importance of soil physical properties (such as soil aeration) in governing soil quality and on-farm production.

Visual scoring (VS)

Each indicator is given a visual score (VS) of 0 (poor), 1 (moderate), or 2 (good), based on the soil condition observed when comparing the paddock sample with three photographs in the field guide manual. The scoring is flexible, so if the sample you are assessing does not clearly align with any one of the photographs but sits between two, a score in between can be given, for example 0.5 or 1.5. An explanation of the scoring criteria accompanies each set of photographs.

Because some soil factors or indicators are relatively more important for soil quality than others, VSA provides a weighting factor of 1, 2 or 3. For example, soil structure is a more important indicator (a factor of 3) than clod development (a factor of 1). The score you give each indicator is multiplied by the weighting factor to give a VS ranking. The total of the VS rankings gives the overall ranking score for the sample you are assessing. Compare this with the score ranges at the bottom of the page to determine whether your soil has good, moderate, or poor soil quality.

The soil quality assessment is not a combination of the scores from the soil and plant score cards. Placing the soil and plant indicator assessment of soil quality side by side at the bottom of the plant indicator scorecard should prompt you to look for reasons if there is a significant discrepancy between the soil and plant indicators. The soil management guidelines for hill country land uses (Volume 4) can help you do this.

CARRYING OUT THE VISUAL SOIL ASSESSMENT

The VSA tool kit

The equipment needed for the VSA 'tool kit' is simple and inexpensive. It comprises:

- 1 spade – to dig out a 20 cm cube of topsoil.
- 1 plastic basin (approx. 35x35x19 cm) – to contain the soil when carrying out the drop shatter test.
- 1 hard square board (approx. 26x26x1.8 cm) – to fit the bottom of the plastic basin on to which the soil cube is dropped for the shatter test.
- 1 heavy duty plastic bag (approx. 74x49 cm) – on which to spread the soil, after the shatter test has been carried out.
- 1 tape measure to measure topsoil depth.
- 1 VSA field guide (weather proof) – to make the photographic comparisons.
- 1 pad of score cards – to record the VS for each indicator. Soil quality under both hill country pastoral grazing and forestry can be assessed using the soil indicator score card, while the plant indicator score card addresses only plant performance under pastoral grazing. The soil and plant score cards have been printed back-to-back. See examples on pp. 13 & 14.

THE PROCEDURE

1. When should soil quality assessment be carried out?

The following recommendations are given as a general guide:

- For pastoral land uses – Test once a year in late winter or early spring.

VSA can be carried out effectively and reliably over a range of soil moisture levels, a characteristic that enhances the robustness of VSA as a tool. However, for best results, you should carry out the VSA when you judge the soil moisture content to be sufficiently dry to prevent compaction by stock treading and wheel traffic, but not dry.

If you're not sure, apply the 'worm test'. Take a piece of soil (half the volume of your index finger) and press firmly to form a 'pencil' with your fingers. Roll the soil into a 'worm' on the palm of one hand with the fingers of the other until it is 50 mm long and 3 mm thick. Exert sufficient pressure with your fingers to reduce the diameter of the worm to 3 mm in 15 – 20 complete forward and back movements of the fingers. If the soil cracks before the worm is made, or if you cannot form a worm (for example, if the soil is sandy), the soil is suitable for testing. If you can make a worm 2 mm thick without it cracking, the soil is becoming susceptible to pugging and is therefore too wet to test.

The 'worm' test

As long as the soil moisture condition is right, test at a similar time each year. This will make your results more comparable from year to year.

For forestry land uses – Test before and after harvest, and before planting. To explain poor tree performance, an assessment would also be useful when the trees are young, seedlings are most vulnerable up to 4 years of age, and growth differences are most easily seen before canopy closure. The soil moisture conditions for sampling are the same as outlined above for pastoral land uses.

2. Setting up

It is important to be properly prepared to carry out soil quality assessments.

- Time – Allow about 20 minutes per site. The assessment process takes about 15 minutes to complete the soil indicator score card, and 5 minutes to complete the plant indicator score card for each site. Sample three or four sites in the paddock for a representative assessment of soil quality.
- Reference sample – Take a small soil sample from under the fence. The paddock to be sampled will have had a history of grazing or tree/scrub cover. Taking a spade-depth sample from under a fenceline where there has been little if any treading, allows you to see the relatively unaltered soil. This helps you give the correct visual score to the soil colour indicator, and allow you to make an immediate comparison with some of the other soil indicators.
- Sites – Select sites that are representative of a particular landform, aspect and slope. It is important to identify the landform, aspect and slope of your site because they are not only very variable in hill country, but they can have a strong influence on soil properties, stock grazing, pasture and tree growth, and soil erosion. Wet areas, for example, will generally be more susceptible to compaction and pugging than dry. Where

haulers are used for harvesting forests, any spurs or high points will tend to be scalped, while those around the boundaries will be relatively intact.

Note the micro-topographical feature you are assessing. For example, whether you are on a stock track or backslope, a skid zone for hauling logs, or on an old landslide site. Record the position of the sites as accurately as you can so you can come back to them for future monitoring. The simplest way to do this is to note the number of paces along a fenceline from the paddock gate, and in from the fenceline, or the number of paces and the bearing from a prominent, stable landmark. Sites can also be marked on aerial photographic plans.

- Set up the gear – At the chosen site, put the square of wood in the bottom of the plastic basin, and spread out and anchor down the plastic bag beside it.

3. Site information

Complete the site information section at the top of the score card. Then record any special aspects you think relevant in the notes section at the bottom of the reverse side of the score card. For example, prolonged wet winter; soil heavily pugged by stock in mid-August; major soil slips during heavy storm in July; logs harvested during summer dry period with little or no apparent wheel-traffic damage, etc.

4. Carrying out the test

- Take the test sample – Dig out a 20 cm cube of topsoil with the spade. If the topsoil is less than 20 cm deep, trim off the upper subsoil before moving on to the next step. The sample provides the soil from which more than half the soil state indicators are assessed.
- The drop shatter test – Drop the same test sample a maximum of three times from a height of 1 m (waist height) onto the wooden square in the plastic basin. Transfer the soil onto the large plastic bag and grade so that the coarsest clods are at one end and the finest aggregates are at the other end (as shown in the "Instructions" section, p25).

The drop shatter test – Drop the same test sample a maximum of three times from a height of 1 m (waist height) onto the wooden square in the plastic basin. Then transfer the soil onto the large plastic bag and grade so that the coarsest clods are at one end and the finest aggregates are at the other end (as shown in the "Instructions" sections).

Systematically work through the score card, assigning a VS to each indicator by comparing the soil laid out on the plastic bag with the photographs and description in the relevant section of the field guide.

5. The plant indicators

You can normally complete the plant indicator score card at the time you carry out the soil indicator assessment, by comparing your observation of the pasture with the photographs in the field guide manual, and by recollection. The drought-stress indicator, for example, requires your recollection of the effect of a dry summer on your pasture. Ideally, the most appropriate time to complete the plant indicator score card is during early to mid-spring, immediately before or at the start of grazing.

The plant indicators are scored and ranked in the same way as soil indicators: a weighting factor is used to indicate the relative importance of each indicator, with each contributing to the final determination of soil quality. The ranking score is the total of the individual VS rankings in the right-hand column. Plant indicators for forestry are not provided, and therefore, soil/plant response comparison can not be made under forestry.

SPECIAL USES OF VSA

The VSA procedure can be used to assess particular characteristics, and at any depth. For example:

- During winter, there was severe pugging of the top 10 cm of topsoil – Instead of taking one 20 cm cube of topsoil, take two 20x20x10 cm samples from 0 to 10 cm depth and combine to form a single sample. Take another two 20x20x10 cm samples from 10 to 20 cm depth, and again combine to form a single sample. Test each combined sample separately and compare the results. The comparison will demonstrate the degree to which the upper part of the topsoil has been damaged by treading compared with the lower topsoil.
- A severely compacted subsoil is suspected at 20–30 cm depth as a result of forestry vehicle traffic – Again, as described above, take a 20 cm cube of topsoil and two combined samples from 20 to 30 cm depth, test separately and compare the results.

USING THE VSA RESULTS

VSA allows you to assess soil quality in a paddock or forest, but does not solve any identified soil quality issues. Once soil is degraded it can take a long time (sometimes decades) to recover. Land managers need to know the moisture content at which their soils are susceptible to treading damage, for example, and how to determine this on the farm. They also need to be able to determine the ongoing physical condition of their soils if they are to manage their farms or forests sustainably. To help land managers preserve or improve soil quality, guidelines are included in Volume 4 for the sustainable management of hill country land uses with specific emphasis on pastoral grazing.

SCORE CARD

Visual indicators for assessing soil quality under hill country land uses

SOIL INDICATORS

Date:

Land use:

Site location ☐ Track ☐ Back slope

Landform: ☐ Ridge ☐ Shoulder ☐ Upper slope ☐ Mid slope ☐ Lower slope ☐ Other

Soil type: Aspect: Slope angle:

Textural qualifier: ☐ Sandy ☐ Loamy ☐ Clayey

Moisture condition: ☐ Dry ☐ Slightly moist ☐ Moist ☐ Wet

Seasonal weather conditions: ☐ Dry ☐ Wet ☐ Cold ☐ Warm ☐ Average

Visual Indicator of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Degree of soil erosion (Fig. 1, p.17)		× 3	
Surface relief (Fig. 2, p.19)		× 1	
Topsoil depth (Fig. 3, p.21)		× 2	
Humus type (Fig. 4, p.23)		× 2	
Soil structure & consistence (Fig. 5, p.25)		× 3	
Soil porosity (Fig. 6, p.27)		× 3	
Soil colour (Fig. 7, p.29)		× 2	
Number and colour of soil mottles (Fig. 8, p.31)		× 2	
Earthworm counts (Fig. 9, p. 33)		× 2	
RANKING SCORE (Sum of VS rankings)			

Soil Quality Assessment	**Ranking Score**
Poor	< 10
Moderate	10 – 25
Good	> 25

If your soil quality assessment is moderate or poor, guidelines for sustainable management are given in Volume 4.

PTO

SCORE CARD

Visual indicators for ranking soil quality under pastoral grazing on hill country

PLANT INDICATORS

Visual Indicator of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Pasture composition (Fig. 10, p. 37)		×3	
Pasture growth and regrowth rates* (Fig. 11, p. 39)		×3	
Pasture utilisation* (Fig. 12, p. 41)		×1	
Area of bare ground (Fig. 13, p. 43)		×3	
Drought stress (Fig. 14, p. 45)		×2	
Stock carrying capacity and fertiliser use* (Fig. 15, p. 47)		×2	
RANKING SCORE (Sum of VS Rankings)			

* Perceived

Soil Quality Assessment	**Ranking Score**
Poor	<10
Moderate	10 – 20
Good	>20

SUMMARY

Soil quality assessment		Do the soil and plant indicators give a different soil quality assessment? If so, why?
SOIL INDICATORS	Plant indicators	

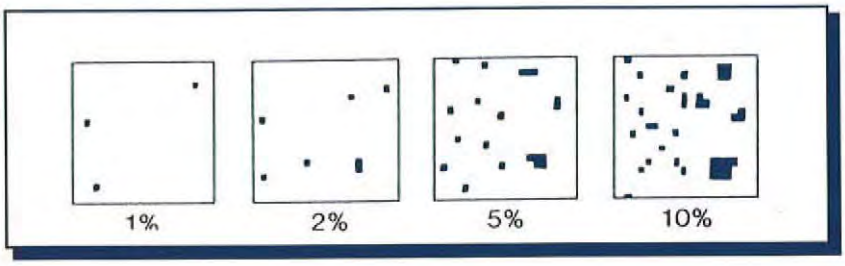
NOTES:

INSTRUCTIONS FOR ASSESSING SOIL QUALITY UNDER HILL COUNTRY LAND USES

SOIL INDICATORS

Degree of soil erosion

- Assess the percent ground area on the hill face affected by soil erosion – slip, slump, flow, rill, gully, creep & sheet erosion and debris tails. Compare your visual observation with the three photographs opposite. The percentage chart below will help you determine surface area of erosion as a percentage of the ground surface



SOIL EROSION can remove large quantities of soil off-site by slips, flows, gullying and rilling, or can reposition the soil semi-intacted by slumping. Surface erosion of topsoil (sheetwash, rilling,) can reduce dry matter production by 20 to 60%, and can significantly reduce feed utilisation and stock carrying capacity. Mass movement erosion by slumps, earthflows, tunnels and gullies can reduce pasture growth by 40 to 80 %, while earthslips and soil slips can initially reduce pasture production by 100% . Over-sowing and topdressing can restore pasture cover, however, pasture production remains depressed by 10 to 40%, and pastures are more susceptible to drought stress. Pastures are also slow to recover on landslide scars, and can take 40 years to reach 75% of uneroded levels. Recovery rate can depend on the accumulation rate of topsoil washed onto the scar from the surrounding embankment, and on the underlying rock and its degree of fracturing. Nutrient losses through erosion may easily exceed the removal of nutrients by the plant.

Soil erosion can have significant off-farm effects, including reduced water quality through increased sediment and nutrient loading in streams and rivers.

FIGURE 1: Visual scoring (VS) of the **degree of soil erosion**

GOOD CONDITION
VS = 2
Less than 1% of the area is affected by soil erosion.

MODERATE CONDITION
VS = 1
1–5% of the area is affected by soil erosion.

POOR CONDITION
VS = 0
More than 5% of the area is affected by soil erosion.

Surface relief

- Observe the surface relief (smoothness) of the ground surface at the end of winter/early spring.
- Compare it with the three photographs opposite.
  Although soils are most susceptible to pugging during the wet winter months, observations of surface relief at any time of the year will give useful information on damage caused by past grazing, and its likely effects on soil condition.

SURFACE RELIEF shows the severity of pugging under stock treading, and indicates structural damage below the surface. Wet soil can pug severely under intensive grazing, and particularly under heavier weight (>400 kg) stock. Pugging reduces the pores in the soil, which are important for water, nutrient and air movement, and root penetration. Surface relief can also be severely modified by rutting under wheel traffic and hauling logs under wet conditions in forests.

FIGURE 2: Visual scoring (VS) of **surface relief**

GOOD CONDITION
VS = 2
Surface is relatively smooth and unbroken.

MODERATE CONDITION
VS = 1
Surface is somewhat broken up and penetrated by occasional heavy treading events but is not difficult to walk over.

POOR CONDITION
VS = 0
Surface is very broken and deeply penetrated by severe repeated treading. The terrain is difficult to walk across and care must be taken to avoid twisting ankles.

Topsoil depth

- Remove a 20 cm cube of topsoil with a spade and set aside for the drop-shatter test. Measure the depth of topsoil in the exposed hole, or from the 20 cm cube, and compare it with the three photographs opposite. If the depth of topsoil is deeper than 20 cm, continue digging the hole until you reach its base. Topsoils are usually darker in colour (and better structured) than the upper subsoil. The base of the topsoil is identified where the soil changes colour. Most topsoils in New Zealand are less than 20 cm deep.
  The depth of topsoil can be measured at any time of the year.

THE PRODUCTIVITY AND STABILITY OF A HILL SOIL is reflected by the depth of the topsoil. Soil structure is generally most strongly developed in the topsoil and contains most of the soil organic matter. Deeper topsoils also have a higher water-holding capacity due to their ability to hold and store more plant-available water. Consequently, topsoils provide an important source of nutrients, air and water for pastures and trees, and provide an important rooting medium for growth and support of plant roots. Because most plant root mass occurs in the topsoil, topsoil depth is a major contributor to pasture production, and to the growth and development of tree seedlings and cuttings. Pasture production on topsoils less than 10 cm deep is often 10% and 40% lower than on deeper topsoils. The base of *Pinus radiata* seedling cuttings are planted at about 15 cm depth, and seedling mortality is high if planted in shallow topsoils less than 10–12 cm deep.

Topsoil depth contributes greatly to soil's ability to absorb heavy rainfall (the soil sponge effect) without becoming saturated. This reduces water moving off-site as overland flow into waterways. Waterloggging and overland flow also causes landslides, and rill and sheetwash erosion.

FIGURE 3: Visual scoring (VS) of **topsoil depth**

Visual score (VS)	Topsoil depth
2	Topsoil depth is greater than 20 cm.
1	Topsoil depth is between 12 and 20 cm.
0	Topsoil depth is less than 12 cm.

Humus types as influenced by land use

- Assess the speed of decomposition on the soil surface by estimating how long plant litter is intact above the soil surface. Mull (less than 1 year); Moder (1 to 2 years); Mor (2 to over 7 years).

  The Mor humus has 3 distinct layers: The leaf-litter (L 2–10 cm); the fermented mid-litter layer (white fungi are visible throughout) (Of 2–4 cm); and the decomposed organic material (Oh 2–8 cm) over leached topsoil (AE horizon).

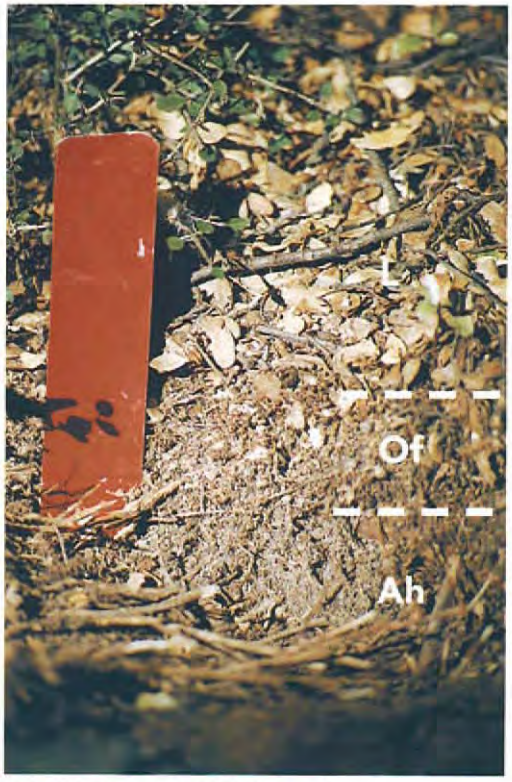
HUMUS is an early indicator for soil quality development. Decomposition rates of plant litter and the type of humus incorporated into the soil affects nutrients and water availability. It controls soil life and affects soil structural development, soil stability and aeration. Humus type can easily be identified within a decade of land use change. Any land-use change can produce humus types outside their natural range, which is defined by climate, clay nutrient reserves and vegetation. For example: Mor humus naturally forms under vegetation adapted to grow under wet and cold montane conditions or on very infertile soils. Elsewhere, litter from such plants degrades more fertile soils.

A MULL HUMUS TYPE shows favourable decomposition dynamics. Earthworms incorporate plant litter within a few months, and the association of humus with clay develops a deep, resilient topsoil. Under mull humus, we typically measure pH 5–7 and C/N ratios of 10–15. Many *native* and *deciduous broadleaf trees, high-fertility grasses, legumes* and *herbs* produce mull humus (refer to Management Guidelines for Hillcountry land uses, section "*Plant-up*".)

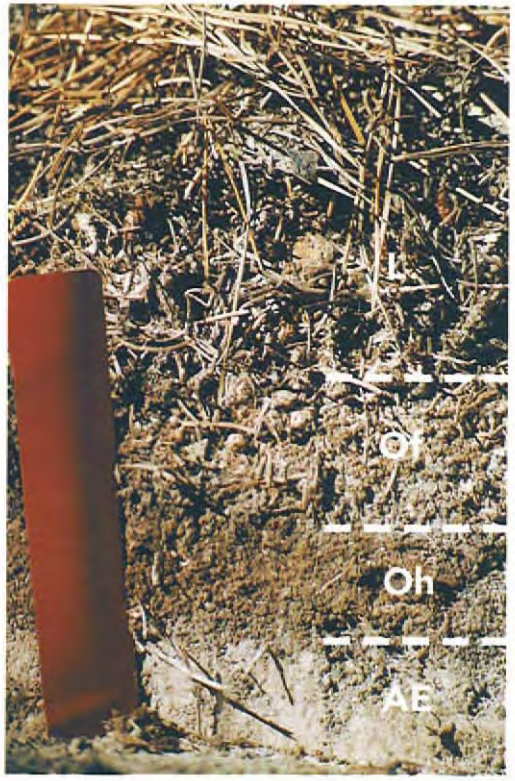
THE MODER HUMUS TYPE shows a somewhat slowed decomposition process. Typical topsoil depth is shallow. Soil humus and nutrients are leached, where moder- or mor-forming vegetation replaces mull-forming vegetation. Moder humus typically has a pH of 4 to 5 and a C/N ratio of 15 to 30. Moder can commonly be found under some *beech, kanuka, oak* and in *low fertility pastures.*

A MOR HUMUS TYPE shows that the decomposition process is severely inhibited. This results from plant litter that resists decomposition, and includes *pines, eucalypts, spruce, douglas fir, cypresses, heather and kauri.* Mor humus typically has a pH of 3 to 4 and a C/N ratio of >30. It leaches topsoil and depletes soil nutrients. The inherent fertility of the underlying soil determines whether such effects are reversible. Permanent changes result if the soil's clays lack nutrients, but where clays contain nutrient reserves, soils can recover under mull-forming vegetation within decades to centuries.

GOOD CONDITION VS = 2
Mull humus type. Rapid decomposition. Few/no plant remains on the surface other than wood.
Photo: Native broadleaf litter



MODERATE CONDITION VS = 1
Moder humus type. Decomposition is slower with a continuous leaf litter covering the surface. Moder soil surface litter is 2–5 cm deep.
Photo: Native black beech litter



POOR CONDITION VS = 0
Mor humus type. Severely inhibited decomposition. Mor soil-surface litter layers are continuous and 5 cm to more than 10 cm deep. Photo: *Pinus radiata* litter

FIGURE 4: Visual scoring of surface **humus types**

Soil structure and consistence

- Take a 20 cm cube of topsoil removed with a spade. If the topsoil is less than 20 cm deep, slice off the upper subsoil before testing, and discard.
- Drop the soil sample a maximum of three times from a height of 1 metre (waist height) onto the firm base in the plastic basin. If large clods break away after the first or second drop, drop them individually again once or twice. If a clod shatters into small (primary structural) units after the first or second drop, it does not need dropping again. Don't drop any piece of soil more than three times.
- Separate each clod from enmeshing roots, and part it by hand along any exposed fracture planes or fissures.
- Transfer the soil onto the large plastic bag.
- Move the coarsest fractions to one end and the finest to the other end. This provides a measure of the aggregate-size distribution. Compare the resulting distribution of aggregates with the three photographs opposite.

GOOD SOIL STRUCTURE is vital for growing good pastures and trees (see pasture composition and growth rates on pp. 30–32). It regulates soil aeration and gaseous exchange rates, the movement and storage of water, soil temperature, root penetration and development, nutrient cycling, and resistance to structural degradation. Good structure also increases the number of days during the year when the soil will support the hoof pressure of heavy animals or vehicle tyres without any negative effects.

FIGURE 5: Visual scoring (VS) of **soil structure and consistence**

POOR CONDITION VS = 0
Soil dominated by extremely coarse, very firm clods with very few finer aggregates.

MODERATE CONDITION VS = 1
Soil contains significant proportions of both coarse firm clods and friable, fine aggregates.

GOOD CONDITION VS = 2
Soil dominated by friable, finer aggregates with no significant clodding.

Soil porosity

- Remove a spade slice of soil from the side of the hole created by taking the 20 cm cube of topsoil, or take a number of clods from the aggregate distribution test.
- Examine for soil porosity, comparing with the three photographs opposite.

SOIL POROSITY, particularly the number of large pores (macropores), controls the movement of air and water in the soil. It is important to assess soil porosity as well as aggregate-size distribution. Soils with good structure have a high porosity between and within aggregates, but soils with large structural units may not have macropores and coarse micropores within the large clods, and therefore may not be adequately aerated. Restricted air and water movement reduces root activity and pasture and tree growth.

GOOD CONDITION VS = 2
Soils have many macropores between and within aggregates associated with readily apparent good soil structure.

MODERATE CONDITION VS = 1
Soil macropores between and within aggregates have declined significantly but are present on close examination of clods showing a moderate amount of consolidation.

POOR CONDITION VS = 0
No macropores or coarse micropores are visually apparent within compact, massive structureless clods that typically show smooth faces with sharp angles, and have few cracks or holes.

FIGURE 6: Visual scoring (VS) of **soil porosity**

Soil colour

- Compare the colour of a handful of soil from the soil structure test with soil taken from under the nearest fence line, or from an undisturbed site that is untrafficked by forest machinery.
- Using the three photographs below, compare the relative change in soil colour that has occurred. As topsoil colour can vary between soil types, the photographs illustrate the trend rather than the absolute colour of the soil.

SOIL COLOUR is a useful indication of soil drainage, soil wetness from late autumn to early spring, and whether the soil is being damaged by pugging or vehicle traffic. Grey subsoil colours in loamy, silty or clayey soils suggest the soil is poorly drained. Grey soil colours in the topsoil suggest the soil has become gleyed due to waterlogging and a deficiency of oxygen for long periods. Poor aeration leads to a build-up of carbon dioxide and methane, and reduces the ability of plants to take up water and nutrients, particularly nitrogen, phosphorus and potassium. Poor aeration also slows the breakdown of organic residues, and can induce chemical reactions toxic to plant roots.

GOOD CONDITION VS = 2
Dark coloured topsoil indicating a well-aerated soil with a good turnover of organic matter, or no change in colour.

MODERATE CONDITION VS = 1
The colour of the topsoil is somewhat paler due to the early stages of gleying because of moderate pugging or wheel traffic.

POOR CONDITION VS = 0
Soil colour has become significantly paler due to gleying because of persistent pugging or wheel traffic.

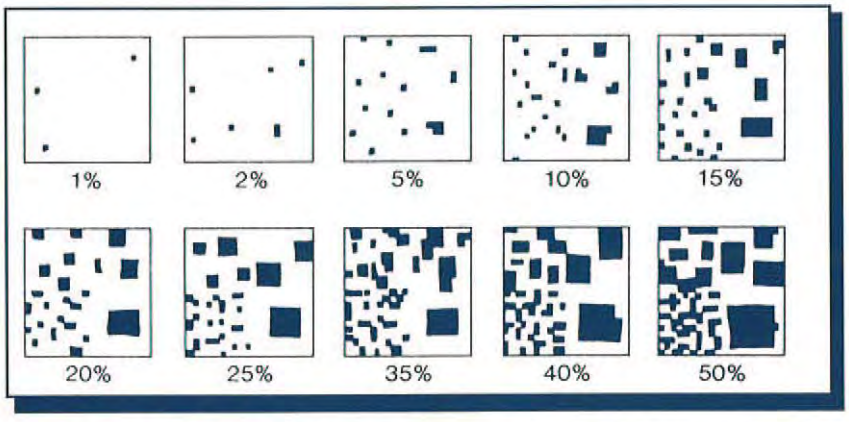
FIGURE 7: Visual scoring (VS) of **soil colour**

Number and colour of soil mottles

- Assess the number, size and colour of mottles by comparing the side of the soil profile, or a number of soil clods from the soil structure test, with the three photographs opposite. In forestry, the number and colour of mottles down to 30 to 45 cm are also important.

  Mottles are spots or blotches of different colour interspersed with the dominant soil colour.

  The percentage chart below will help you determine the percent of the soil occupied by mottles.



THE NUMBER, SIZE AND COLOUR of mottles indicate how well the soil is drained and how well it is aerated. They are also an early warning of a decline in soil structure, and show whether the soil is being damaged by pugging or compaction. Loss of soil structure reduces the number of channels and pores in the soil that conduct air and water. This results in a deficiency of oxygen and a build-up of carbon dioxide. As oxygen depletion becomes more severe and prolonged, orange, and ultimately grey, mottles form. A high proportion of grey mottles indicates the soil is waterlogged and starved of oxygen for much of the year. Poor aeration reduces the uptake of water and plant nutrients, particularly nitrogen, phosphorus and potassium. Poor aeration also retards the breakdown of organic residues, and can induce chemical reactions that form chemicals toxic to plant roots.

FIGURE 8: Visual scoring (VS) of **number and colour of soil mottles**

POOR CONDITION VS = 0
Soil has abundant (>50%), medium and coarse orange and grey mottles.

MODERATE CONDITION VS = 1
Soil has common (10–25%), fine and medium orange and grey mottles.

GOOD CONDITION VS = 2
Mottles are generally absent.

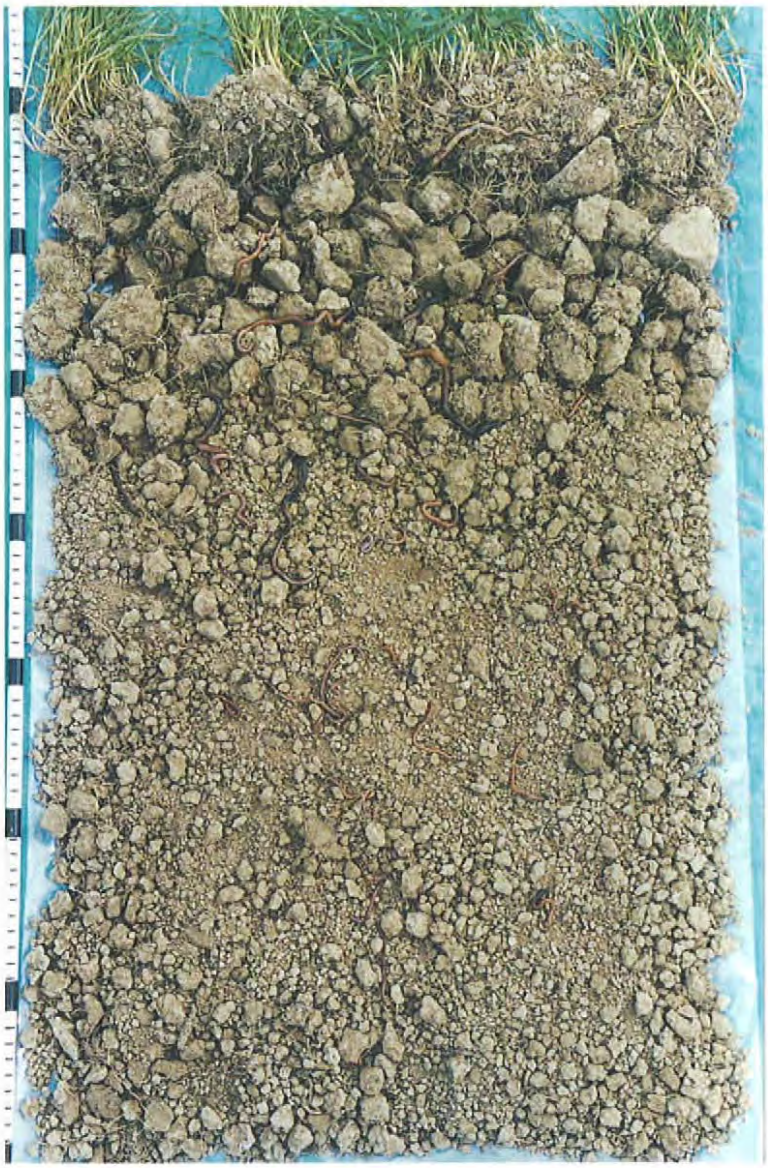
Earthworm counts

- Sort carefully through the soil sample used to assess soil structure and consistence, and count the earthworms found in a 5-minute search. Pay particular attention to the turf mat. Earthworms vary in size and number depending on the season, so for year-to-year comparison, earthworm counts must be made at the same time of year, and preferably during the winter. The class limits for earthworm numbers given opposite are based on the probability that you will find only two-thirds of the worms present during a 5-minute search.

  (Earthworm numbers are commonly reported on a square-metre basis. A 20-cm-cube sample is equivalent to one twenty-fifth of a square metre, and so the number of earthworms counted should be multiplied by 25 to convert to a square metre basis. If your sample depth is only 0–10 cm, the same class limits and conversion factors apply, because common earthworms are most abundant in the upper topsoil).

THROUGH THEIR BURROWING, feeding and casting, earthworms play a major role in decomposing and cycling organic matter, and in supplying nutrients. They can also improve soil porosity and aeration, water infiltration and conductivity, aggregate size and stability, root growth and subsequent pasture productivity. Earthworm numbers can decline (3-fold) under severe pugging and can have adverse long-term effects on nutrient cycling, organic matter decomposition, soil structure and porosity.

FIGURE 9: Visual scoring (VS) of **earthworm counts**



Visual score (VS)	Earthworm counts (per 20 cm cube of soil)
2	>15
1	5–15
0	<5

INSTRUCTIONS FOR ASSESSING SOIL QUALITY UNDER PASTORAL GRAZING ON HILL COUNTRY

PLANT INDICATORS

Pasture composition

- Assess the botanical composition of the pasture (the proportion of each species present) in the winter or early spring.

PASTURE SPECIES vary according to grazing pressure, soil fertility and hoof damage. They also vary in their tolerance of poor soil aeration, waterlogging and pugging. Consequently, their nitrogen uptake, dry matter production and survival ability also vary markedly. Meadow fescue, meadow foxtail, *Poa trivialis*, creeping bent, pennyroyal, hawkbit, ragwort, buttercup, mayweed, duckweed and dock are tolerant of waterlogging, due to pugging or poor drainage. Perennial ryegrass, white clover, chewing fescue, browntop, *Poa annua*, and crested dogstail are moderately tolerant of waterlogging. Cocksfoot, sweet vernal, *Poa pratensis* (Kentucky bluegrass), goose grass, danthonia, ratstail, meadow rice grass and yarrow are sensitive to waterlogging and will die out if wet conditions persist.

PASTURE COMPOSITION will also change according to the degree of treading damage. Ryegrass and, to a lesser degree, hawkbit, *Poa pratensis*, pennyroyal and goose grass resist treading damage better than many other species, with ryegrass often becoming dominant in pugged pastures. *Poa trivialis*, browntop and white clover are moderately tolerant to treading. Cocksfoot, yorkshire fog, *Poa annua* and red clover, and many low fertility pasture species such as sweet vernal, crested dogstail, birdsfoot, chewing fescue, meadow foxtail, and creeping bent are sensitive to intensive treading and disappear under prolonged pugging. Treading damage and bare ground exposure will also allow invasion by opportunist species such as white clover and *Poa annua*, more vigorous weeds, and less desirable pasture species. Light pugging, however, can open up the thick mat of low fertility species and allow the spread of perennial legumes and the establishment of preferred grasses, e.g. ryegrasses.

FIGURE 10: Visual scoring (VS) of **pasture composition**

GOOD CONDITION VS = 2
Depending on soil fertility, pastures generally have a good mix of browntop, ryegrass, sweet vernal, crested dogstail, white clover, cocksfoot, yorkshire fog, and one or two herbs such as plantain, yarrow and dandelion; few weeds. In higher fertility systems, the proportion of perennial ryegrass and *Poa* is higher.

MODERATE CONDITION VS = 1
Pasture species with a range of tolerances to waterlogging and stock treading are present, and pastures may contain a number of weeds and forage herbs including dock, ragwort, thistles, hawkbit, mayweed, pennyroyal and plantain. The proportion of browntop, sweet vernal and cocksfoot has declined somewhat from that originally sown, while ryegrass/white clover, *Poa trivialis*, *Poa pratensis* and goose grass has increased.

POOR CONDITION VS = 0
Pastures are often dominated by species that are more tolerant of poor aeration and waterlogging due to pugging, by species such as ryegrass and *Poa pratensis* that are more tolerant of stock treading, and by species such as white clover that are quick to colonise bare ground created by severe pugging. Weeds are also very common and may include ragwort, hawkbit, pennyroyal, thistles, buttercup, duckweed and dock. Pasture composition has little relationship to the original seed mix.

COURTESY OF DES COSTALL

Pasture growth and regrowth rates

- Assess pasture growth and regrowth rates since the last grazing by pasture probe, rising plate or herbage cut measurements. If this information is not available, use visual approximations of dry matter production levels.

  For a reliable comparison, make assessments at the same time of year, preferably in early spring.

HIGH PASTURE GROWTH RATES depend on good soil structure and fertility, the availability and unrestricted movement of water and air through the soil, and on the season and seasonal weather conditions. Treading damage on compacted moist soils can reduce pasture production by up to 27 percent, but on pugged (deformed) wet soils, the reduction can be as much as 50 percent. Pasture regrowth rates on wet soils can be reduced by 20–30 percent. In addition to fattening stock, good dry matter production, quality pastures and rapid regrowth are required before tupping, and so that stock will be in good condition at lambing and calving.

FIGURE 11: Visual scoring (VS) of **pasture growth and regrowth rates**

Visual score (VS)	Pasture growth and regrowth rate
2	Good pasture growth and regrowth.
1	Moderate pasture growth and regrowth.
0	Poor pasture growth and regrowth.

Pasture utilisation

- Assess pasture utilisation by the proportion of pasture that has been grazed, and by the proportion not smeared by or trampled into the mud by grazing animals (see opposite).
  Assess pasture utilisation during the wet winter months after or near the end of a grazing cycle.

DEGRADED SOILS have a low load-bearing capacity. As a result, pastures on these soils are easily trampled into the mud, or the leaf surface of exposed grass smeared by soil particles when wet. This makes them both inaccessible and unpalatable to stock. Trampling can reduce pasture utilisation by 20–40 percent.

FIGURE 12: Visual scoring (VS) of **pasture utilisation**

Visual score (VS)	Pasture utilisation
2	Good pasture utilisation with only a little of the pasture being smeared by soil particles.
1	Moderate utilisation with a significant amount of pasture being smeared by soil particles, and trampled into the mud.
0	Poor utilisation with a large proportion of pasture being smeared by soil particles, and trampled into the mud.

Area of bare ground

- Compare the surface of the soil with the three photographs opposite. If there is canopy closure, part the pasture with your hands and score at ground level. Assessment of an area of bare ground after a long dry period will show how much pasture has died from lack of moisture.

  Assess the area of bare ground in winter or early spring.

IN ADDITION TO STOCK CAMPING and drought effects, bare ground is formed by the physical churning up of the soil from treading and pugging. This causes leaf and stem crushing, uprooting or burial of plants, and root damage, which reduce pasture density and vigour. Weeds and less desirable pasture species can invade the resulting gaps, further reducing pasture production. Like surface relief, the area of bare ground can be a good indicator of below-ground damage.

FIGURE 13: Visual scoring (VS) of **area of bare ground**

GOOD CONDITION
VS = 2
The tiller and root density of the pasture is sufficiently high to cover all or most of the ground surface area.

MODERATE CONDITION
VS = 1
Pasture shows significant areas of bare ground and the invasion of weeds and clover caused by hoof damage.

POOR CONDITION
VS = 0
Large areas of bare ground occur because of treading damage and the subsequent reduction in the density and vigour of pasture plants

PHOTOS COURTESY OF DES COSTALL

Drought stress of pastures during dry periods

- Assess, from visual evidence and local knowledge, the degree to which pastures are drought stressed during dry periods by comparing the greenness of the pasture with the three photographs opposite.
- Assess the level of dry-matter production, and whether drought-tolerant species have become dominant in the pasture sward.

THE DEGREE OF DROUGHT STRESS in dry periods depends on climatic conditions, the drought tolerance of the pasture, and the water-holding capacity of the soil. The last is governed by soil depth and texture, organic matter content, and the number and size of soil pores. Pastoral soils with a good soil structure have a large number of macropores and coarse and medium-sized micropores, and, subsequently, have a higher water-holding capacity than degraded soils with few pores.

GOOD CONDITION VS = 2
Non-drought tolerant pastures 'brown off' significantly during dry summer months, although thin green patches are still present close to the ground. Dry matter production is very low and pastures become dominated during drought by the more drought-resistant cocksfoot, danthonia, goose grass, chewing fescue, birdsfoot, meadow rice-grass, rats tail, yarrow, sheep sorrel, dock and small annual clovers. Deep rooted flat weeds such as plantain and hawkbit may also be common.

MODERATE CONDITION VS = 1
Pastures remain relatively green, and dry matter production is able to hold on, albeit at low levels, further into dry summers. Pasture composition is dominated by sweet vernal, crested dogstail, Poa annua, chewing fescue, ryegrass and white clover during dry periods.

POOR CONDITION VS = 0
With the possible exception of drought-tolerant species, pastures brown off completely and pasture growth stops during dry periods. Pastures die off during times of prolonged drought. With the exception of subterranean clover, pastures take a long time to come away in autumn. Soil structure becomes brittle and turns to dust under treading.

FIGURE 14: Visual scoring (VS) of **drought stress** of pastures during dry periods

Stock-carrying capacity and fertiliser use

- Assess stock-carrying capacity, based on your knowledge of the paddock.
- Is additional fertiliser needed to maintain stocking capacity?

PASTURE PRODUCTION CAN RECOVER almost completely within approximately 6 months following moderate soil compaction. Severe compacting and pugging, however, can reduce dry matter production by up to 40–45 percent. If feed utilisation ratios are around 0.7, this decline in pasture production would reduce potential stock numbers by 10–20 percent. To offset this trend, additional fertiliser is often applied to maintain dry matter production and stock numbers.

FIGURE 15: Visual scoring (VS) of **stock-carrying capacity and fertiliser use**

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Visual score (VS)	Stock-carrying capacity and fertiliser use
2	Standard fertiliser applications maintain stock-carrying capacity.
1	Some additional fertiliser is required to maintain stocking rates.
0	Significant additional fertiliser is required to maintain stocking rates, especially during pinch periods.

Environmental and economic sustainability of hill country land uses can be greatly influenced by soil quality. The visual soil assessment method (VSA), described in this *Field Guide*, provides land managers with a simple tool to assess and monitor soil quality. Visual soil properties are diagnostic of soil quality, and provide an effective and immediate way to assess soil quality quickly and cheaply in the field.

VSA is based on the visual scoring of key bio-physical indicators of soil quality, and incorporated on an easy-to-use scorecard. The soil indicators are supported by plant 'performance' indicators that link soil condition to pasture production. The indicators are underpinned by extensive research, and are linked to economic performance. Soil indicators used are generic, and have the major advantage of being largely independent of soil type. This enables the VSA to be applied throughout the country.

The VSA *Field Guide* is self explanatory, and its use does not require special training or technical skills. While the *Field Guide* contains a wealth of information about soil quality and its fundamental importance to sustainable resource and environmental management, the information is expressed in a simple and concise way, and will provide a useful educational tool.

Pick up a spade, and have a go!

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